The occurrence of lymphocystis in *Micropogon undulatus* and *Cynoscion arenarius* from Mississippi estauries [1]

by

J. Y. Christmas and H. D. Howse
Gulf Coast Research Laboratory

ABSTRACT

Lymphocystis was observed in Atlantic croakers (*Micropogon undulatus*) and sand seatrouts (*Cynoscion arenarius*) collected from brackish waters of the Mississippi Gulf Coast. This is the first report of lymphocystis in fishes of the Gulf of Mexico and adds one family and two species to host records.

Microscopic examination of the tumors revealed several histologic differences in the lesions of the two species. Mature tumor cells in the croakers were larger than those in the sand seatrout. In the croakers, these cells were closely packed and their hyaline capsules were usually confluent. In the sand seatrouts, the tumor cells were rarely confluent and were usually widely separated either by interstitial connective tissue or by an amorphous, hyaline matrix that filled the intercellular spaces. A preliminary description of the histology of the neoplasm was included.

Ecological factors of the sampling stations where fishes infected with lymphocystis occurred were compared with stations where lymphocystis was not encountered. The pollution load was much greater in estuarine systems where lymphocystis was encountered. The chemical and physical differences observed at these stations were discussed.

INTRODUCTION

Since the first published account (Lowe 1874) of lymphocystis in fishes, the literature concerning this disease has become extensive. The

[1]This study was conducted in cooperation with the Department of the Interior, Bureau of Commercial Fisheries, under Public Law 88-309, Projects 2-24-R and 2-42-R.

gross and microscopic morphology of the tumor, as well as its viral etiology, are now well known. Since several recent reviews (Nigrelli and Smith 1939, Weissenberg 1954, Nigrelli and Ruggeri 1965, Sinderman 1966) of the literature are available, it is not necessary to discuss the history of lymphocystis here. In their review, Nigrelli and Ruggieri (1965) included an annotated bibliography of papers on lymphocystis. They also provided, in tabular form, a list of all host species of the virus. This list comprises 49 species of 20 families in 5 orders of fishes.

In March 1966, in conjunction with the Cooperative Gulf of Mexico Estuarine Inventory and Study Project, we began extensive sampling of the fauna in Mississippi Sound and adjacent waters. This study area included four estuarine systems which are, from east to west, *vid.* Fig. 1.: Pascagoula River, Biloxi Bay, St. Louis Bay and Pearl River. In a sample that was taken on January 13, 1967, we found one fish that exhibited tumorous lesions on its body and fins. We tentatively diagnosed the disease as lymphocystis and subsequently searched for diseased fishes in all of our trawl samples.

Little information concerning the environment in which lymphocystis infected fishes are found is available. Therefore, we have given special attention to several physical characteristics of our sampling stations throughout the entire period of sampling. These findings and our observations on the histology of the lymphocystis lesions in the Atlantic croaker *(Micropogon undulatus)* and the sand seatrout (*Cynoscion arenarius)* form the basis of this report.

MATERIAL AND METHODS

At least one trawl sample was scheduled for collection at monthly intervals at each of 35 of the 50 estuarine stations located in Mississippi Sound and adjacent waters of the Mississippi Gulf Coast, *vid.* Fig. 1. All stations were established between March 1966 and January 1967. Consequently, at least two years of sampling was scheduled for all stations. Trawl samples were scheduled for collection every other week at stations 13, 32, 37, 33, 34, 36, 31 and 35. Two samples (one daytime and one nighttime) were scheduled for collection at monthly intervals at each of 6 off-shore stations located at ten fathom contour intervals between the 5 and 50 fathom curves in the Gulf of Mexico.

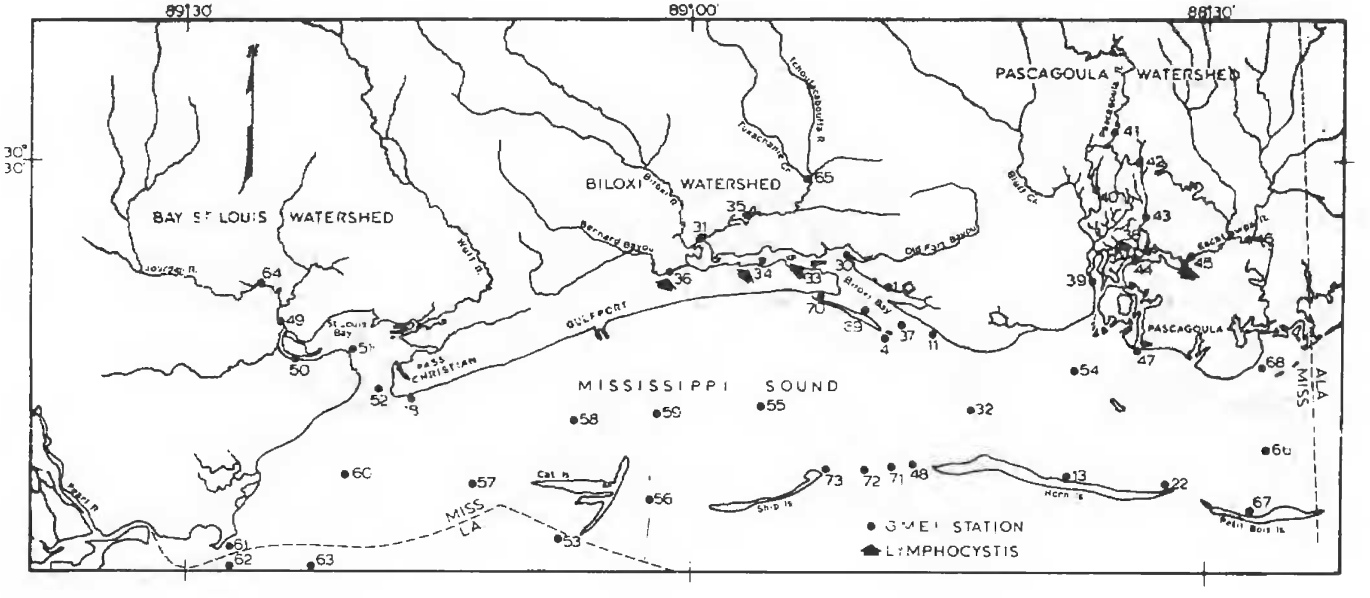


Figure 1. Mississippi estuarine study area showing location of GMEI permanent station.

Figure 2. Atlantic croaker (*Micropogon undulatus*) (A) and Sand seatrout (*Cynoscion arenarius*) (B) showing extensive lymphocystis lesions.

Figure 3. Caudal region of B, Figure 2 showing large mass and numerous solitary tumors.

vary in size and shape. Tumor cells in the croakers (Figs. 4 and 5) are irregular to ovoid in shape; in the sand seatrouts (Figs. 6 and 7) they are circular to ovoid. In the croakers, these cells measure up to 163 x 350 u in their short and long diameters respectively; in the sand seatrouts, they measure up to 150 x 188 u. Each cell is surrounded by a distinct hyaline capsule that, in the large cells, measures about 2.6 u in thickness (Figs. 4 through 8).

Each small differentiating tumor cell contains a single, centrally located nucleus embedded in a large amount of granular cytoplasm. A network of chromatin-like inclusion bodies is present in the cytoplasm of the larger differentiating tumor cells. These inclusion bodies are confined to the perinuclear region of the cell.

A large, eccentrically located nucleus is present in each mature tumor cell (Figs. 5 and 8). These cells also contain large amounts of granular cytoplasm. In each of the completely differentiated tumor cells, the number of inclusion bodies is markedly increased and they form an elaborate network at the cell periphery (Figs. 5, 6 and 8).

Normal tissue is mainly confined to regions of the tumor that contain small differentiating cells. This tissue surrounds each young tumor cell and is composed of the usual dermal cellular and connective tissue elements. Numerous capillaries are present. Normal tissue is infrequently encountered surrounding the mature tumor cells (Fig. 9). Hence, the hyaline capsules of these cells in *Micropogon undulatus* are either confluent or separated from each other only by thin strands of connective tissue (Figs. 5 and 8). However, the tumor cells in *Cynoscion arenarius* are widely separated either by connective tissue or an amorphous, hyaline matrix into which the hyaline capsules blend (Figs. 6 and 7) although the outer boundaries of the capsules remain discernible.

Physical characteristics of the environment: The specimens observed in this study were collected from eight of the trawl samples taken at estuarine stations 33, 34, 36 and 45 in the winter months between 13 January 1967 and 20 February 1969.

Ten specimens were obtained at three adjacent stations (Fig. 1) located in the Biloxi Back Bay area. Eight of these were collected at: Station 36 (30^0 27′ 24″ N, 88^0 56′ 24″ W) in Bayou Bernard. Two

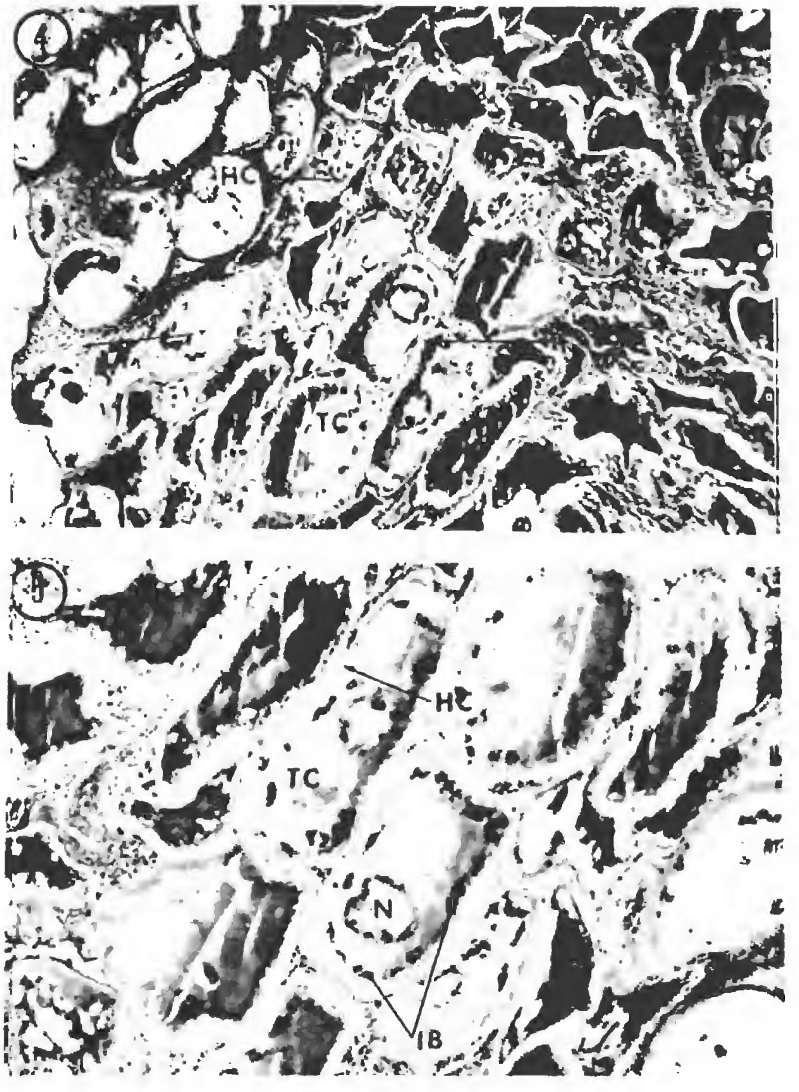


Figure 4. A section through a lymphocystis tumor from *Micropogon undulatus*. Mature tumor cells (TC) are shown in the left side of the photomicrograph and young tumor cells in the right side. Note the hyaline capsule (HC) around each tumor cell. (Arrows) - normal tissue. Hematoxylin-Eosin. 90 X.

Figure 5. A higher power view of a portion of the preceding figure showing the network of inclusion bodies (IB) at the cell periphery. (N) - nucleus; (HC) - hyaline capsule. Hematoxylin-Eosin. 160 X.

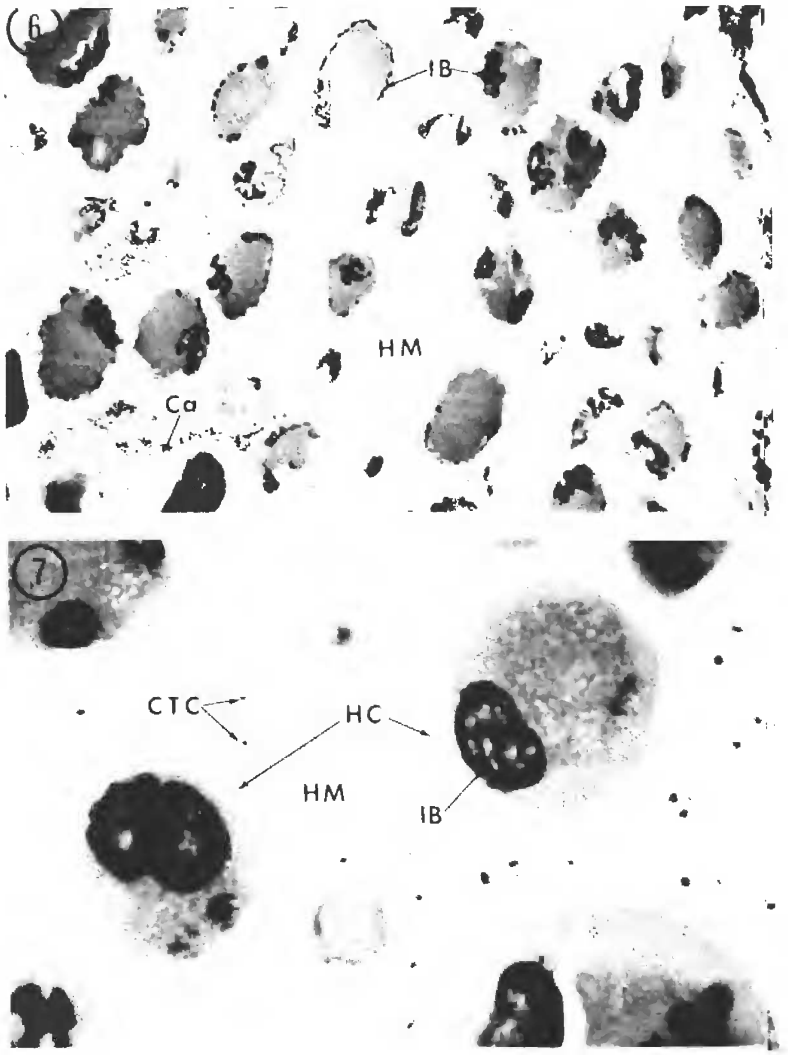
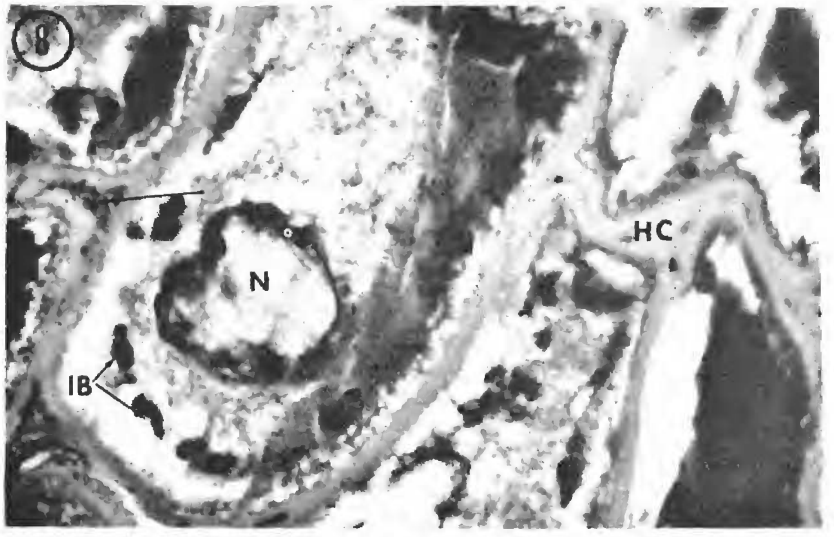
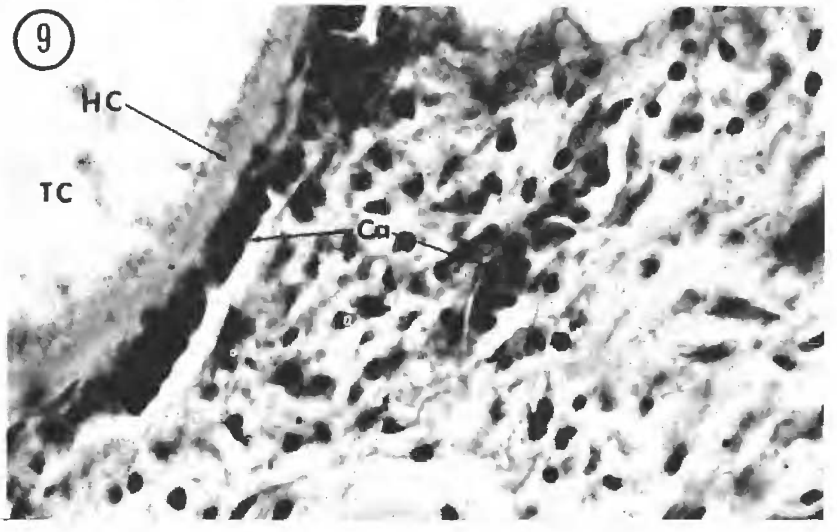


Figure 6. A section through a lymphocystis tumor from *Cynoscion arenarius.* Note that the tumor cells are rounded and widely separated from one another by a hyaline matrix (HM). Compare with Figure 4. (Ca)-capillary; (IB)-inclusion bodies. Hematoxylin-Eosin. 109 X.

Figure 7. A section through the hyaline matrix in the tumor from *Cynoscion arenarius.* Note the hyaline capsule (HC) and the connective tissue cells (CTC). (HM)-hyaline matrix; (IB)-inclusion bodies. Hermatoxylin-Eosin. 492X.





Section 8. Section through mature lymphocystic tumor cells from *Micropogon undulatus*. Note the large nucleus (N) and network of inclusion bodies (IB). Note also that the hyaline capsules (HC) of adjacent tumor cells are confluent. (Arrow) connective tissue. Hematoxylin-Eosin. 400X.

Figure 9. A view of intercellular connective tissue and the edge of a mature tumor cell (TC) from *Micropogon undulatus*. Note capillaries (CA) filled with erythrocytes. (HC)-hyaline capsule. Hematoxylin-Eosin. 896 X.

TABLE 1. - Occurrence of lymphocystis in fishes of the Mississippi estuaries and associated data for each collection.

Date	Sta.	No. Caught	Total length mm Min	Max	W/ly*	Water Depth Feet	Bottom Water Temp C°	Sal ppt	DO ppm	pH	Phosphate, uga/1 Ortho	Total	Nitrate ugs/1
						Micropogon undulatus							
1-13-67	36	667	55	280	220	12	11.1	01.7	----	----	-----	-----	-----
1-26-67	36	70	48	185	147	10	17.0	06.1	5.2	5.0	-----	-----	-----
2-9-67	36	51	136	277	231	11	11.2	02.2	8.8	5.0	-----	-----	-----
2-22-67	45	39	35	226	201	18	11.2	27.2	8.9	7.0	-----	-----	-----
					224								
2-23-67	36	29	23	216	159	10	14.0	02.2	7.8	6.8	-----	-----	-----
2-23-67	34	73	18	174	157	15	13.9	05.6	6.8	7.9	-----	-----	-----
11-27-68	33	3	127	144	144	12	16.0	24.4	12.7	7.9	.60	2.00	.31
2-20-69	36	122	146	225	146	10	11.9	12.2	8.5	6.4	2.00	4.50	2.70
						Cynoscion arenarius							
11-13-68	36	39	49	172	95	9	14.0	13.3	-----	7.2	3.00	9.75	.29
					172								
12-10-68	36	2	81	181	181	10	15	6.7	5.4	6.8	3.00	6.00	6.23

*/ Specimens with lymphocystis

TABLE 2 - Summary of Atlantic croakers and sand seatrouts caught by trawl at stations 33, 34, 36, 45 and 50, April 1966 through March 1969.
Figures in ly. column show the number with lymphocystis.

		Micropogon undulatus			Cynoscion arenarius			TOTALS		
Sta.	No. Smpls.	No. Caught	Catch per haul	ly.	No. Caught	Catch per haul	ly.	No. Catch	Catch per haul	ly.
45	22	214	9.7	2	3	0.1	0	217	9.8	2
33	65	5,108	78.6	1	1,603	24.7	0	6,711	103.3	1
34	65	4,210	64.8	1	2,018	31.0	0	6,288	95.9	1
36	65	7,963	122.5	5	5,903	90.8	3	13,866	213.3	8
Sub Tot.	217	17,425	80.3	9	9,527	43.9	3	27,022	124.2	12
50	21	3,040	144.8	0	2,626	125.0	0	5,666	269.8	0
TOT.	238	20,465	86.0	9	12,153	56.7	3	32,688	137.3	12

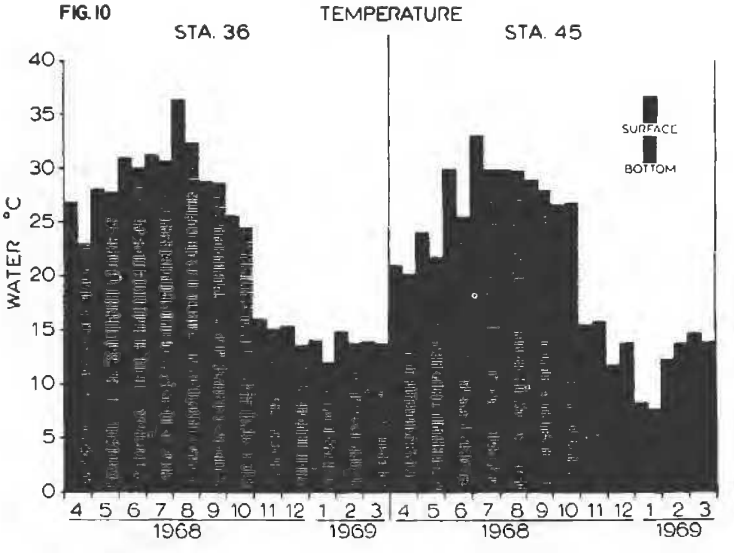
infected specimens were found among the 9,318 Atlantic croakers collected at stations 34 (30° 24' 53" N, 88° 55' 47" W) and 33 (30° 24' 47" N, 88° 52' 33" W). These stations are located in Biloxi Back Bay 6 (9.7 kilometers) and 9 (14.5 kilometers) statute miles respectively, toward the open bay from station 36. These stations generally yielded a large number of numerous estuarine fishes and invertebrates during the entire sampling program. All of the infected sand seatrouts were found at station 36.

Two infected croakers were collected at station 45 (30° 25' 07" N, 88° 13' 17" W) in the Escatawpa River, 2.7 statute miles (4.3 kilometers) above its confluence with the Pascagoula River. Very few fishes and invertebrates were caught at this station.

The pertinent biological and physical data collected with these samples are summarized in Table 1. The lowest and highest bottom water temperatures recorded for these samples were 9.5° and 17.0° C. The minimum and maximum salinity concentrations recorded when infected specimens were found were 1.1 ppt and 27.0 ppt.

Numbers of croakers and sand seatrouts collected at these stations during the entire sampling period (March 1966 to March 1969) are given in Table 2. The numbers of these species caught in the St. Louis Bay system at station 50, where no lymphocystis was observed, are included for comparisons. The catch per haul at station 50 was 21% greater than at station 36 and 96% greater than at station 45.

Lymphocystis infected fishes were not encountered in the other two estuarine systems (St. Louis Bay and Pearl River) nor were any observed among the thousands of fishes, including croakers and sand seatrouts, collected between the above mentioned estuarine stations and the fifty fathom curve station in the Gulf of Mexico. Therefore, a comparison of the physical factors at stations 36 and 45 with those of station 50 (30° 20' 06" N., 89° 22' 25" W.), in the St. Louis Bay system is indicated. Each of the stations is located ten to twelve miles (19.3 kilometers) from the mainland coast line in the estuarine reach of a stream. The data for stations 36 and 45 during the period of April 1968 through March 1969 are shown in Figures 10 through 16. Data derived from the two or three samples collected every month at station 36 are averaged. All data for stations 45 and 50 are based on one sample



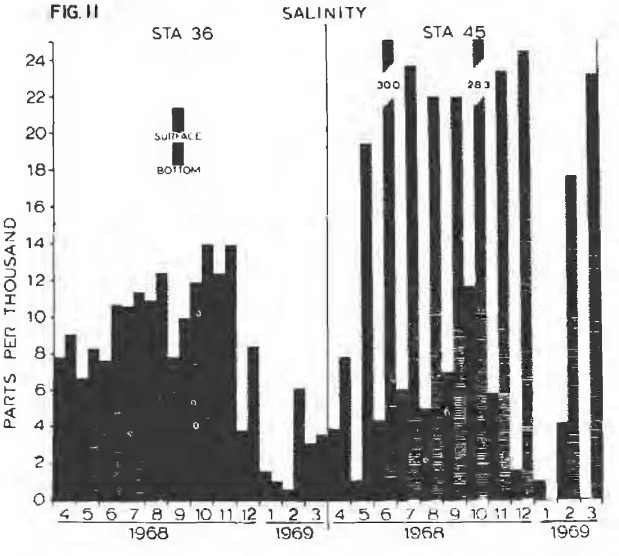
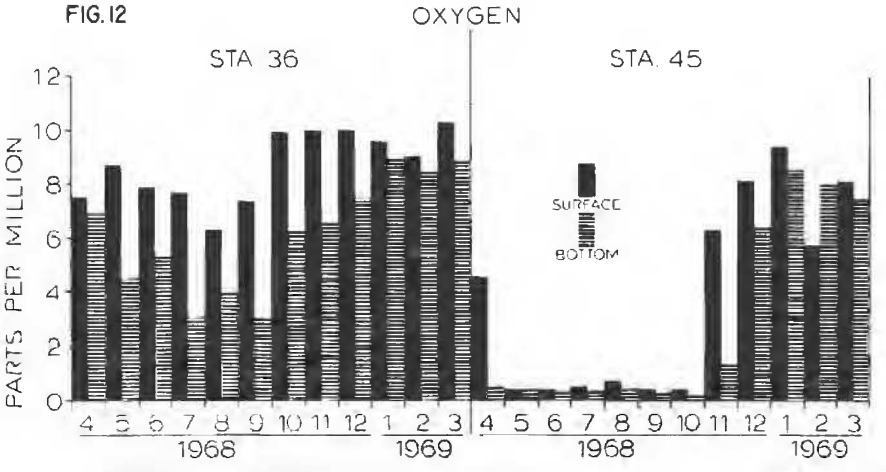


Figure 10. Surface and bottom temperatures at station 36 and 45, May 1968 through March 1969. Data for station 36 are averages of 2 or 3 samples collected during each month. One sample was collected each month at station 45.

Figure 11. Surface and bottom salinities at stations 36 and 45, May 1968 through March 1969. Data for station 36 are averages of 2 or 3 samples collected during each month. One sample was collected each month at station 45.



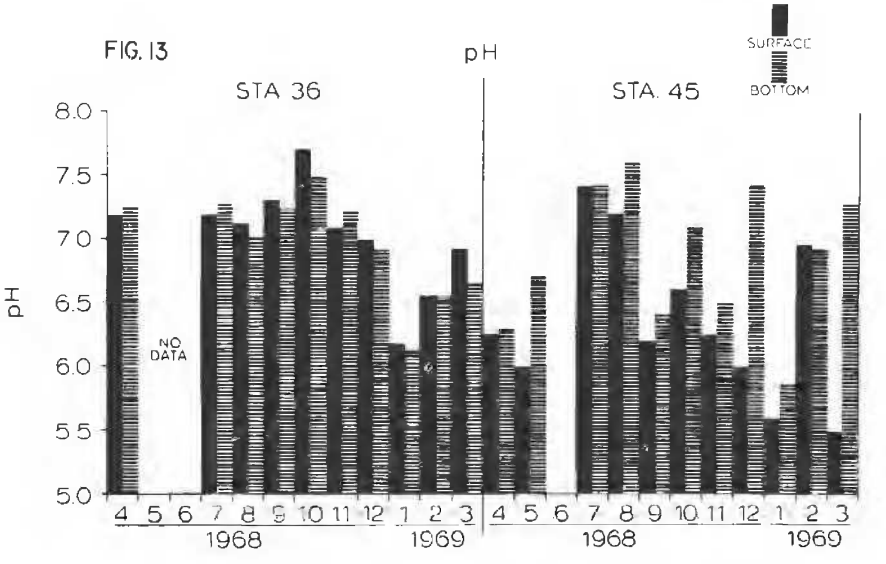
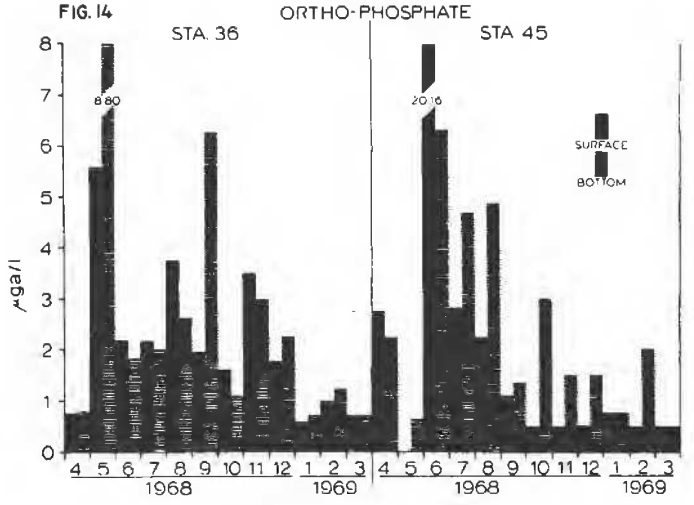


Figure 12. Surface and bottom dissolved oxygen concentrations at stations 36 and 45, May 1968 through March 1969. Data for station 36 are averages of 2 or 3 samples collected each month. One sample was collected each month at station 45.

Figure 13. Surface and bottom pH values at stations 36 and 45, May 1968 through March 1969. Data for station 36 are averages of 2 or 3 samples collected during each month. One sample was collected each month at station 45.



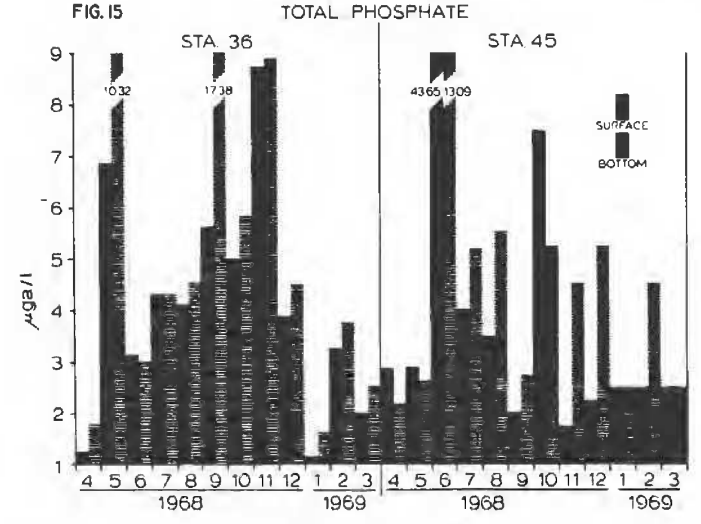


Figure 14. Surface and bottom orthophosphate concentrations at stations 36 and 45, May 1968 through March 1969. Data for station 36 are averages of 2 or 3 samples collected during each month. One sample was collected each month at station 45.

Figure 15. Surface and bottom total phosphate concentrations at stations 36 and 45, May 1968 through March 1969. Data for station 36 are averages of 2 or 3 samples collected during each month. One sample was collected each month at station 45.

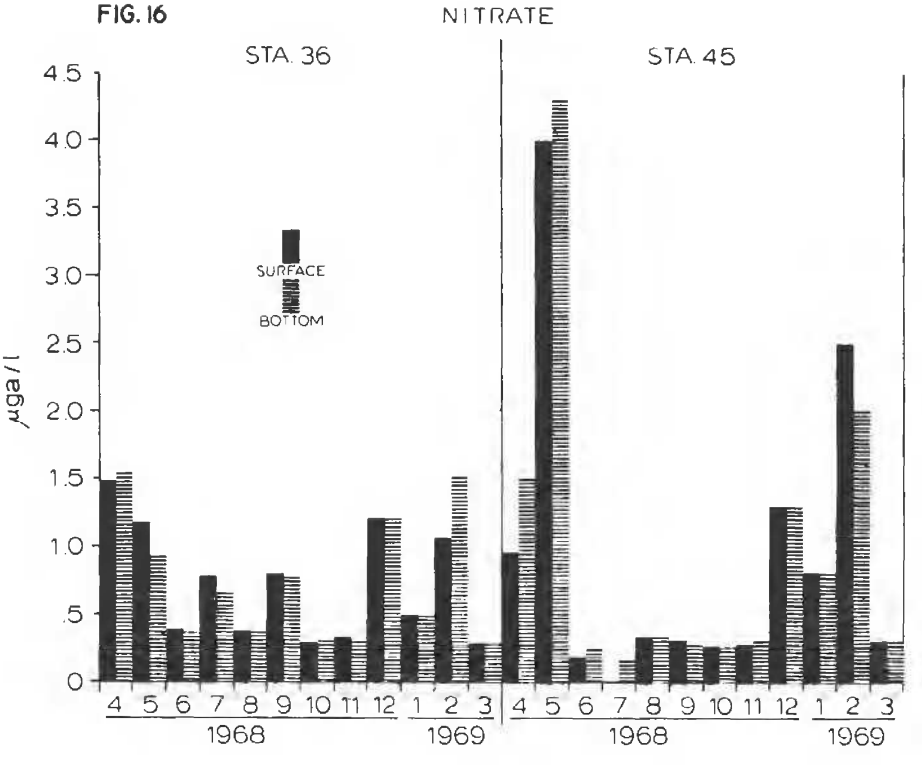


Figure 16. Surface and bottom nitrate concentrations at stations 36 and 45, May 1968 through March 1969. Data for station 36 are averages of 2 or 3 samples collected during each month. One sample was collected each month at station 45.

taken each month.

Water temperatures (Fig. 10, Table 3) at all three stations showed similar seasonal variations. All specimens with lymphocystis were collected after the water temperature had dropped below 15^0 C in the fall and before the spring warming trend. The temperature periodically exceeded 15^0 C during this period and the minimum temperature was about 8^0 C.

The salinity (Fig. 11, Table 3) at all three stations was generally lower during the winter months and fresh water was encountered in the entire water column at each station at least once during the study period. However, elevated bottom salinities were routinely encountered at station 45. This condition is apparently caused by the intrusion of salt water through the Pascagoula Ship Channel (controlling depth 38 ft.). The average surface salinity concentration (4.3 ppt) was lower at station 45 than at either station 36 (7.3 ppt) or 50 (8.2 ppt).

Dissolved oxygen concentrations (Fig. 12, Table 3) at all stations were well above the minimum requirement (5 ppm) for fishes during the winter months when lymphocystis was observed. However, anaerobic conditions persisted at station 45 during most of the remainder of the year. Bottom water oxygen concentrations below 5 ppm at station 36 occurred each month from May through October. Averages (Table 3) were below 5 ppm during July, August and September, 1968. At station 50, the lowest concentration recorded was 6.35 ppm in June 1968. Low oxygen concentration apparently accounts for the small number of specimens collected in the Escatawpa River.

The pH values (Fig. 13, Table 3) were generally a little lower at stations 45 and 36 than at station 50. Water in streams of Pascagoula, Biloxi Bay and St. Louis Bay watersheds usually has a pH value below 6 (Anon 1961-1966) before mixing with sea water in the estuary. The pH value of sea water is usually between 8 and 8.3.

Higher concentrations of ortho-phosphate were observed at stations 45 and 36 (Fig. 14) than at station 50 (Table 3).

Total phosphate concentrations (Fig. 15, Table 3) were extremely high during some months at stations 36 and 45. They exceed the maximum at station 50 several times during the year.

TABLE 3 Monthly records of temperature, salinity, dissolved oxygen, pH, and concentrations of ortho-phosphates, total phosphates and nitrates at stations 45, 36 and 50 for April 1968 through March 1969

	Temp C°		Sal ppt		Oxygen ppm		pH		PHOSPHATE Ortho µgat/l		PHOSPHATE Total µgat/l		NITRATE µgat/l	
STATION 45, Gear Type 5														
Month	Sur.	Bot.	Sur.	Bot.	Sur.	Bot.	Sur.	Bot.	Sur.	Bot.	Sur.	Bot.	Sur.	Bot.
4-68	21.0	20.2	3.9	7.8	4.60	0.50	6.25	6.32	2.88	2.15	2.87	2.20	0.95	1.50
5	23.9	21.8	1.1	19.4	0.41	0.40	5.97	6.71	0.00	0.66	2.90	2.64	4.00	4.30
6	29.9	25.5	4.4	30.0	0.40	0.31	---	---	20.16	6.30	43.65	13.09	0.19	0.25
7	33.2	29.9	6.1	23.9	0.48	0.35	7.42	7.43	2.92	4.68	4.07	5.18	0.00	0.17
8	29.0	29.8	5.0	22.0	0.70	0.46	7.20	7.60	2.25	4.87	3.50	5.55	0.34	0.34
9	29.0	28.0	7.0	22.0	0.40	0.00	6.20	6.40	1.12	1.35	2.00	2.75	0.37	0.29
10	26.6	26.8	11.7	28.3	0.40	0.20	6.60	7.10	0.50	3.00	5.25	10.50	0.27	0.26
11	15.5	15.8	5.8	23.3	6.30	1.84	6.23	6.50	0.50	1.50	1.72	4.50	0.28	0.31
12	11.9	13.9	1.7	24.4	8.19	6.38	5.98	7.43	0.50	1.50	1.50	5.75	1.67	1.35
1-69	8.4	8.1	1.1	0.0	9.40	8.55	5.58	5.86	0.75	0.75	2.50	2.50	0.82	0.82
2	12.4	13.7	4.2	17.7	5.75	8.05	6.96	6.88	0.50	2.00	2.50	4.50	2.50	2.00
3	14.6	13.9	0.0	23.3	8.20	7.45	5.48	7.28	0.50	0.50	2.50	2.50	0.31	0.31
MEAN	21.4	20.6	4.3	20.2	3.77	2.90	6.35	6.86	2.72	2.44	6.25	5.10	0.97	0.99
STATION 36.														
4-68	23.1	22.2	8.4	9.0	8.20	6.94	7.18	7.26	1.06	1.08	1.12	1.12	1.33	1.42
5	26.0	26.6	6.7	8.3	7.80	5.23	---	---	3.45	4.95	4.17	5.81	1.49	1.37
6	31.2	30.9	7.6	10.7	7.91	5.35	---	---	2.18	2.12	3.15	3.42	0.39	0.38
7	31.3	31.2	10.6	11.4	7.71	3.16	7.18	7.30	2.17	2.02	4.34	4.34	0.70	0.66
8	36.4	32.4	10.9	12.4	6.36	4.05	7.12	7.05	3.75	2.63	4.00	4.50	0.37	0.37
9	28.8	27.6	7.8	10.0	7.21	3.10	7.30	7.22	1.95	6.25	5.63	17.25	0.80	0.78
10	25.6	24.5	11.9	13.9	9.99	6.25	7.68	7.47	1.62	1.12	5.00	5.93	0.30	0.32
11	16.0	15.1	17.4	13.9	10.15	6.60	7.09	7.22	3.50	3.00	8.75	8.88	0.34	0.30
12	15.4	13.6	3.9	8.4	10.10	7.67	6.96	6.83	1.75	2.25	3.88	4.50	1.22	1.22
1-69	14.1	12.1	1.7	1.1	9.64	8.97	6.16	6.14	0.50	0.63	1.13	1.63	0.49	0.49
2	14.8	13.8	0.6	6.1	9.03	8.48	6.55	6.55	1.00	1.25	3.25	3.75	1.07	1.57
3	14.5	13.6	3.1	3.6	10.34	8.87	6.89	6.64	0.63	0.63	2.00	2.50	0.28	0.28
MEAN	23.1	22.0	7.3	9.2	8.78	6.35	7.03	6.97	1.95	2.28	3.91	5.32	0.72	0.72
STATION 50.														
4-68	22.4	21.7	8.1	8.9	6.98	6.71	6.35	6.50	1.72	1.50	1.88	1.56	1.42	1.42
5	27.7	27.4	7.2	8.3	7.10	6.63	7.60	7.40	1.56	1.56	1.64	1.64	1.53	1.86
6	31.0	31.1	6.7	7.8	7.96	6.35	8.85	8.20	1.40	3.85	2.10	4.50	.32	.38
7	31.5	30.0	7.2	13.3	7.71	6.65	7.85	7.45	.62	2.48	.90	3.00	.84	1.05
8	30.0	30.0	12.2	12.2	7.30	6.70	---	---	.75	.75	1.75	4.00	.34	.34
9	27.3	26.1	9.7	12.2	8.33	7.49	7.07	7.30	.50	1.00	1.50	3.75	.68	.68
10	27.1	26.9	14.4	16.6	7.71	6.59	7.40	7.50	.50	1.00	1.50	1.87	1.00	.48
11	14.2	14.2	12.2	17.8	10.00	9.90	7.10	7.70	.50	.50	2.00	2.00	.52	.31
12	11.0	10.0	8.9	11.4	11.80	12.80	7.17	7.35	1.00	1.00	2.50	2.00	.82	1.35
1-69	8.9	8.6	4.4	12.8	10.10	10.80	7.74	7.95	.75	.50	1.50	.75	.33	.33
2	16.8	15.8	3.3	9.0	10.60	10.15	6.80	6.55	.50	.50	3.00	3.00	.36	.33
3	11.0	11.8	3.9	12.8	8.80	7.80	7.71	6.90	.50	.50	3.00	3.00	.31	.31
MEAN	21.7	21.1	8.2	11.9	8.70	8.21	7.36	7.35	.87	1.27	1.82	2.47	0.71	0.74

Nitrate concentrations (Fig. 16, Table 3) were similar at all three stations. The averages of concentrations at station 45 were higher because 4.00 and 4.30 *u*ga/1 were recorded in May, 1968.

DISCUSSION

The results of this study confirm the diagnosis of lymphocystis in the Atlantic croaker (*Micropogon undulatus)* and the sand seatrout *(Cynoscion arenarius).* This finding adds one species from each of two genera and one[1] family (Sciaenidae) to the list of fishes that are known to be hosts of lymphocystis.

A single specimen of *Gunterichthys longipenis* "apparently infected with lymphocystis disease" (Dawson 1966) was collected in the Mississippi Sound near the east end of Ship Island in March 1963. However, this observation has not been verified by microscopic examination of the lesion (Dawson, personal communication).

Weissenberg (1945) showed that differences between fish groups are evident in the tumor cells of lymphocystis, especially in the development and configuration of the inclusion bodies. Nigrelli and Ruggieri (1965) stated that subtle differences between species exist but they have not been characterized. In addition to the variation in the maximum size of the mature tumor cells, we found a difference in the intercellular regions of the tumors of our two species. In the sand seatrout, but not in the Atlantic croaker, a hyaline matrix that is morphologically similar to the cell capsule is frequently present in these regions. Neither the origin nor the significance of this matrix was evident. Further structural and histochemical studies of the capsule and matrix are now in progress in our laboratories.

It is interesting that we have encountered only twelve lymphocystis-infected specimens among the thousands of fishes that were collected during the three year sampling period, especially since numerous young, infection-free specimens of several species (*i.e., Lepomis macrochirus, Pomoxis nigromaculatus, Ceratocanthus schoepfi* and others) that are known to be hosts of lymphocystis were present in the samples.

All the diseased fishes observed in this study were obtained during

[1]Two families if Otholithidae is a valid family.

the winter months of three successive years. This finding is in accord with those of other studies (Weissenberg 1945, Hansen 1951, Wolf 1962) which showed that low temperatures (12.5^0 C in Wolf's experiments) favor the outbreak and transmission of lymphocystis in a fish population. However, outbreaks of lymphocystis occur also in the summer months (Nigrelli and Smith, 1939; Witt, 1955). Indeed, in his study of white crappie from the Niangua Arm of the Lake of the Ozarks, Witt (1955) showed that the highest incidence of lymphocystis occurred in July. The occurrence of this disease in some species of of fishes during the summer and other species during winter is not understood. The influence that fluctuations in chemical factors (*i.e.*, oxygen concentration, salinity, pH, etc.) of the environment may have on the incidence and course of lymphocystis is unknown. In order to compare environmental conditions in estuaries, we must also note influences that result from conditions in their respective watersheds and the amount of sediments and pollution contributed by these areas.

Drainage areas of these systems vary markedly. They are as follows: Escatawpa River - 630 square miles (1827.5 square kilometers), Bayou Bernard - 75 square miles (194.2 square kilometers) and Jourdan River - 350 square miles (906.5 square kilometers). The average flow of these streams is approximately 2 feet ^{3}/second (.56 meters ^{3}/second) per square mile of drainage area but with considerable annual variation (Anon. 1961-1966).

Preliminary estimates of gross erosion and annual sediment yields (A.C. Burford, personal communication) indicate that erosion of the Escatawpa River watershed (1993 tons /sq. mi. annually) is greater than that of the Jourdan River watershed (1770 tons /sq. mi. annually). Conversely, the portion of sediment delivered by the Jourdan River (476 tons /sq. mi. annually) through the vicinity of our stations is greater than by the Escatawpa (372 tons /sq. mi. annually). The suspended sediment load in the Bayou Bernard watershed is unknown.

Robertson Lake, in the Escatawpa, and Big Lake at the mouth of Bayou Bernard, located immediately down stream from stations 45 and 36 respectively, collect some of the finer suspended sediment load of these streams by spreading and slowing the flow. Both are shallow areas with soft mud bottom and intertidal mud flats. No comparable condition exists between station 50 and St. Louis Bay.

The lower Escatawpa River and Bayou Bernard are grossly polluted but the Jourdan River is in a relatively pristine condition. Since most of the watershed of each of these streams is located in Jackson, Harrison and Hancock Counties, respectively, examination of the population densities of these counties gives some idea of the relative amount of pollution possible. The estimated 1968 population (Smith 1969) divided by the County area gives the following numbers of persons per square mile: Jackson County - 109.7, Harrison County, 277.4 and Hancock County - 36.7. The population in each county is concentrated along the coast.

Industrial pollution is varied and heavy in both Bayou Bernard and the lower Escatawpa River (Wakefield 1966, Panagiotou 1968). Slow tidal exchange increases the time of stay of pollutants in both streams. No significant industrial pollution exists in the Jourdan River.

No cure for lymphocystis is known (Wolf 1968). Although this disease currently may not be important in wild populations, both the increasing ecological stress (*i.e.*, pollution, and possibly other factors such as boat traffic) on estuarine populations and the mounting interest in mariculture emphasize the importance of determining the relationship between the disease and the physical conditions of the environment. This problem can be clarified only by long range investigations of environment where this disease occurs with some degree of regularity.

The fact that heretofore lymphocystis has not been diagnosed in fishes of the Mississippi Gulf Coast area suggests one of the following interpretations: Lymphocystis has only recently been introduced into the waters of the Mississippi Gulf Coast; the disease has been present indefinitely, but its incidence and course are suppressed by unknown factors; lymphocystis has been present indefinitely, but remained undetected because of the lack of systematic sampling of the fish population in the estuarine and river systems; fish under increasing environmental stress are more susceptible to lymphocystis virus. The observations of this study provide no information as to which of these interpretations is correct.

REFERENCES CITED

Anon. 1961-1966.. Water resources data for Mississippi. United States Department of the Interior, Geological Survey, Water Resources Division. Published as Annual Report.

Dawson, C. E. 1966. *Gunterichthys longipenis*, a new genus and species of ophidioid fish from the northern Gulf of Mexico. Proceedings of the Biological Society of Washington, 79: 205-241.

Hansen, Donald. 1951. Biology of the White Crappie in Illinois. Bulletin Ill. Natural History Survey of Illinois, 25: 211-265.

Lowe, John. 1874. Fauna and flora of Norfolk. Part IV. Transaction of the Norfolk and Norwich Naturalists' Society, pp. 21-56.

Nigrelli, Ross F., and Ruggieri, G. D. 1965. Studies on virus diseases of fishes. Spontaneous and experimentally induced cellular hypertrophy (lymphocystis disease) in fishes of the New York Aquarium, with a report of new cases and an annotated bibliography. Zoologica, 50: 83-96.

Nigrelli, Ross F., and Smith, G. M. 1939. Studies on lymphocystis disease in the Orange Filefish, *Ceratacanthus schoepfi* (Walbaum) from Sandy Hook Bay, N. J. Zoologica, 24: 255-264;

Panagiotou, P. E. 1968. Water pollution control needs of Bernard Bayou. Report to: Mississippi Air and Water Pollution Control Commission, p. 8.

Sinderman, Carl J. 1966. Diseases of marine fishes. pp. 1-89. In F. S. Russell (ed.) Advances in Marine Biology. Academic Press, New York.

Smith, Wilbur and Associates. 1969. Population and economic study for Hancock, Harrison, Jackson and Pearl River Counties. Mississippi Report to: The Gulf Regional Planning Commission, Mississippi. pp. 306.

Wakefield, John W. 1966. Water pollution control in the Escatawpa

River Basin, Alabama and Mississippi. (A Plan for Cooperative Action). Presented before the Jackson County Water Users Committee of the South-eastern Comprehensive Water Pollution Control Project in Pascagoula, Mississippi, September 15, 1966. p. 8.

Weissenberg, R. 1945. Studjes on virus diseases of fish. Part IV. Lymphocystis Disease in Centrarchidae. Zoologica, 30:169-181.

Weissenberg, R. 1965. Fifty years of research on the lymphocystis virus disease of fishes (1914-1964). Annals of the New York Academy of Sciences, 126:362-74.

Witt, A., Jr. 1955. Seasonal variation in the incidence of lymphocystis in the White Crappie from the Niangua Arm of the Lake of the Ozarks, Missouri. Transactions of the American Fisheries Society, 85: 271-279.

Wolf, Ken. 1962. Experimental propagation of lymphocystis disease of fishes. Virology, 18: 249-256.

Wolf, Ken. 1968. Lymphocystis disease of fish, U.S. Department of Interior, Fish and Wildlife Service, Fishery Leaflet No. 458, p. 4.